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Yabusaki et al.

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(54) **TRANSPORT CONTROL SERVER,
TRANSPORT CONTROL SYSTEM, AND
BACKUP PATH SETTING METHOD**

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H04L 45/42 (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

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(56)

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patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.

This patent is subject to a terminal dis-
claimer.

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Aug. 6, 2010, now Pat. No. 8,811,149.

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H04L 12/707 (2013.01)
H04L 12/751 (2013.01)
H04L 12/729 (2013.01)
H04L 12/703 (2013.01)
H04L 12/717 (2013.01)
H04L 12/24 (2006.01)

(52) **U.S. Cl.**

CPC *H04L 45/22* (2013.01); *H04L 41/0654*
(2013.01); *H04L 45/02* (2013.01); *H04L*

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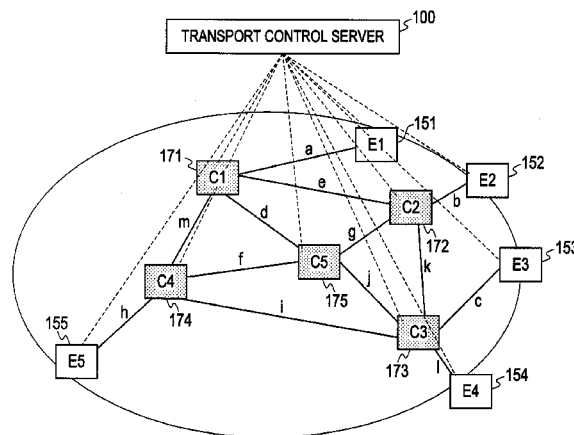
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ABSTRACT

Transport control server (TCS) in a network system including a first backup path (FBP) with predetermined first bandwidth (PFB) secured or reserved between any node pair, second backup path (SBP) with predetermined second bandwidth (PSB) secured or reserved between any node pair, the FBP and SBP sharing a link, each node forwards data according to path setting information. The TCS including: a storage section storing, for each path, an identifier for each node through which the path passes; and a control processing section performing: upon switchover of first active path to FBP, judging whether PSB of SBP can be secured or reserved by the bandwidth of the shared link through which the FBP passes, by referring to the storage section; if not, identifying nodes through which the SBP passes, by referring to the storage section; and transmitting a setting change notification to delete the SBP to the identified nodes.

9 Claims, 16 Drawing Sheets

OVERALL NETWORK ARCHITECTURE



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FIG. 1

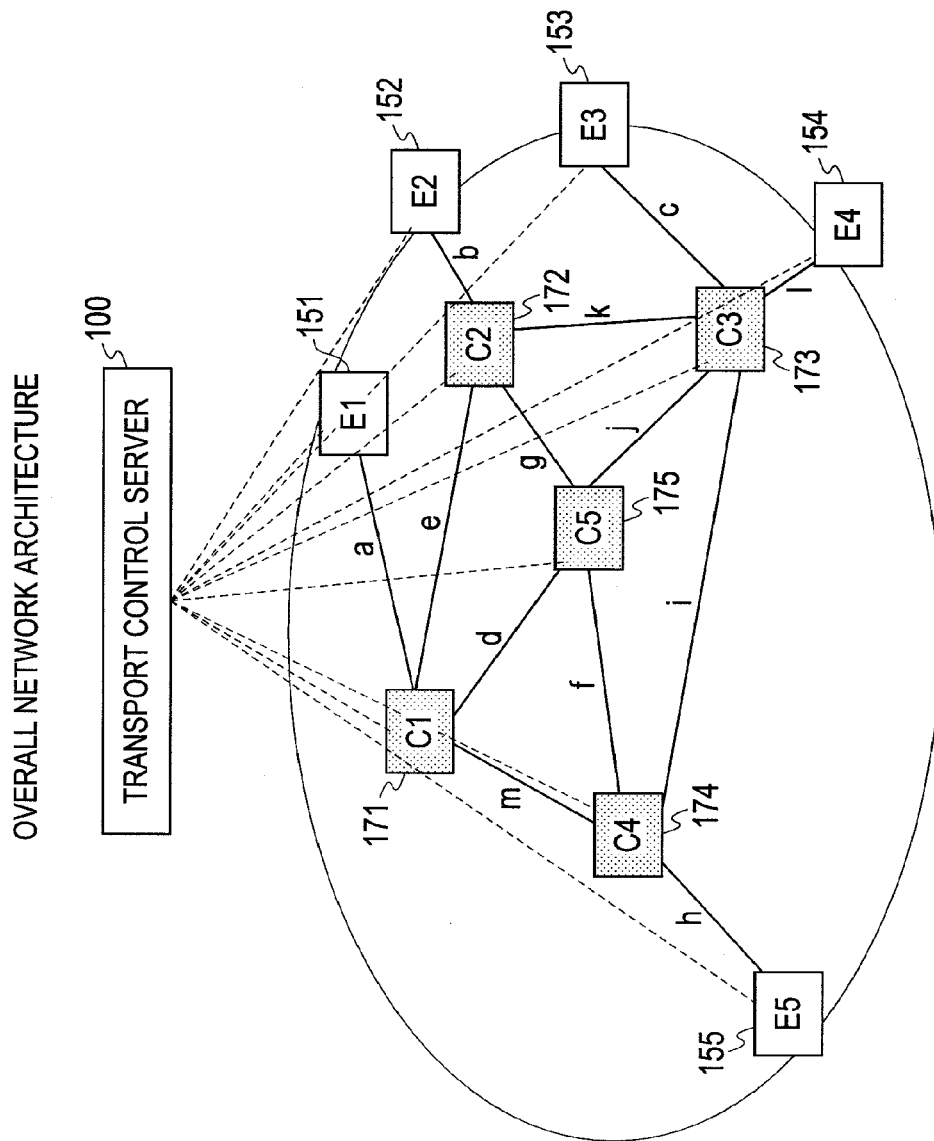


FIG. 2

SERVER-CENTRIC MANAGEMENT BY TRANSPORT CONTROL SERVER

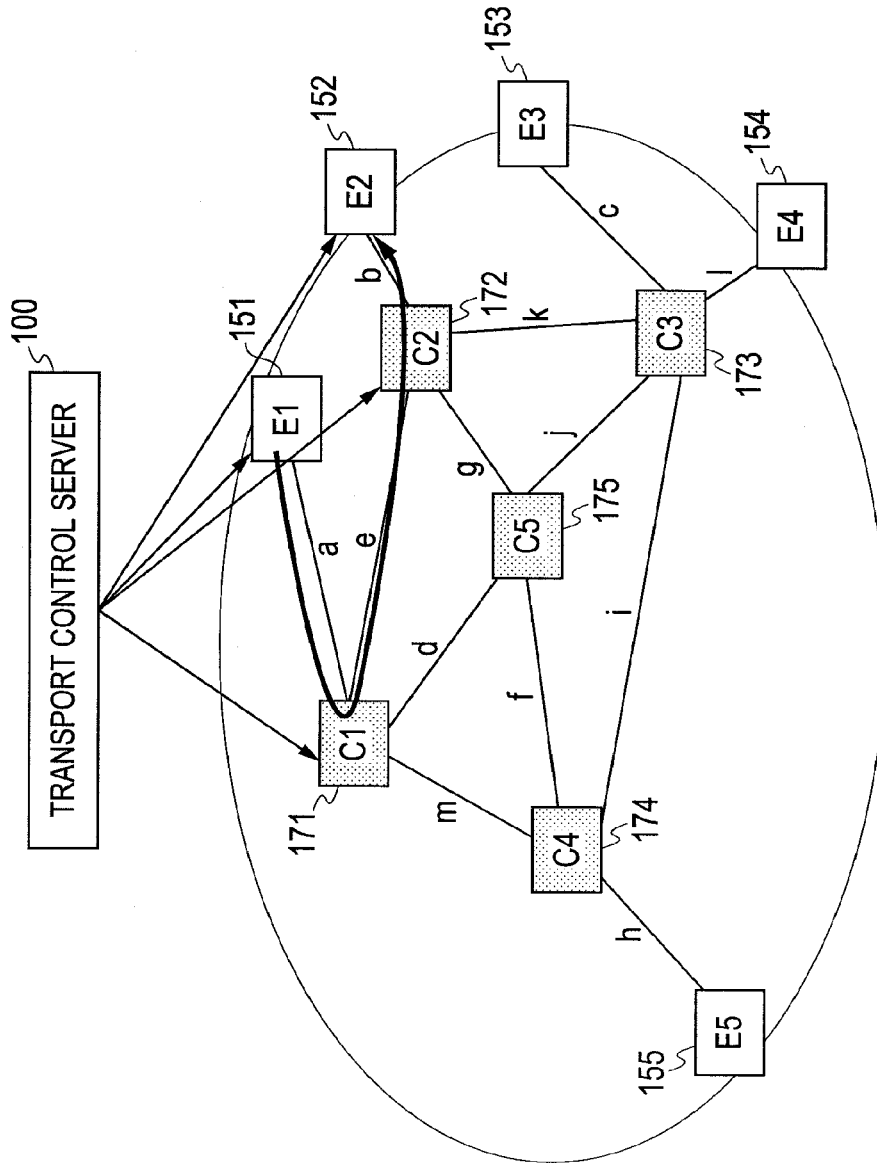


FIG. 3

FORWARDING DATABASE (FD) CHANGE NOTIFICATION UPON A FAULT OCCURRING

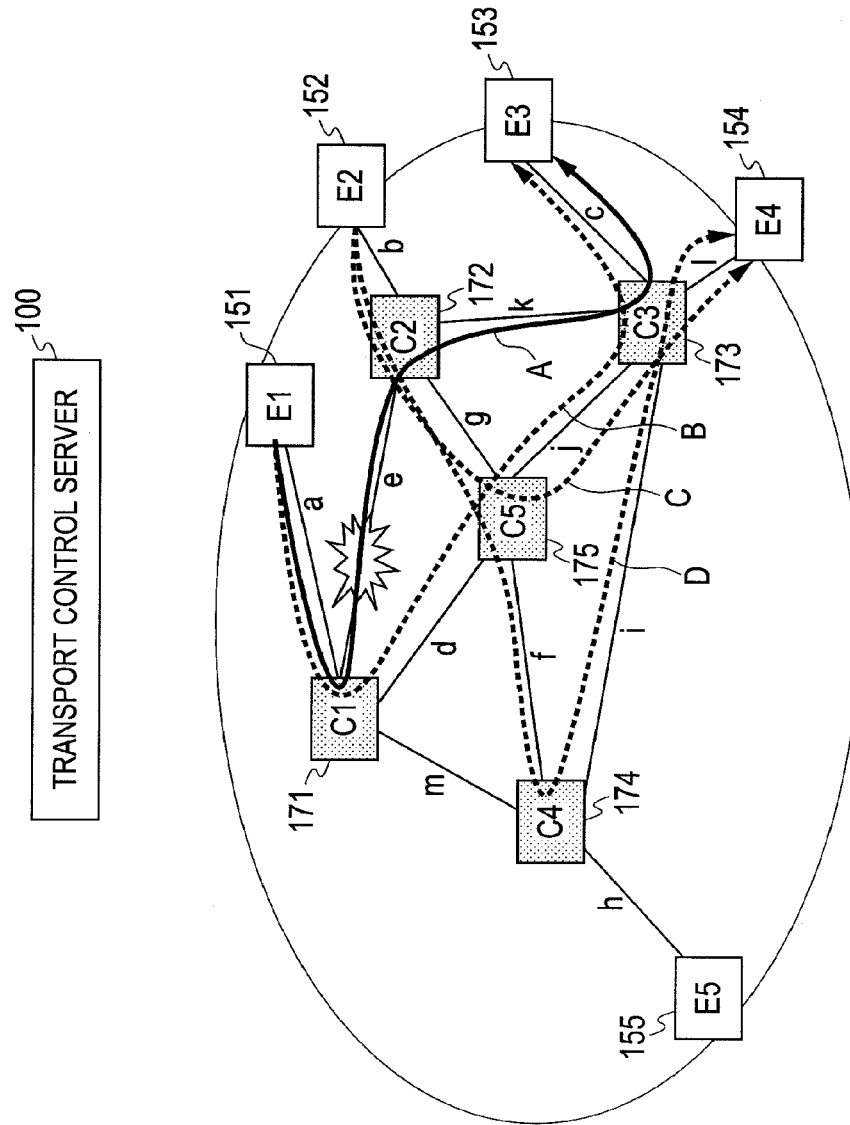


FIG. 4

FORWARDING DATABASE (FD) CHANGE NOTIFICATION UPON A PATH CHANGE

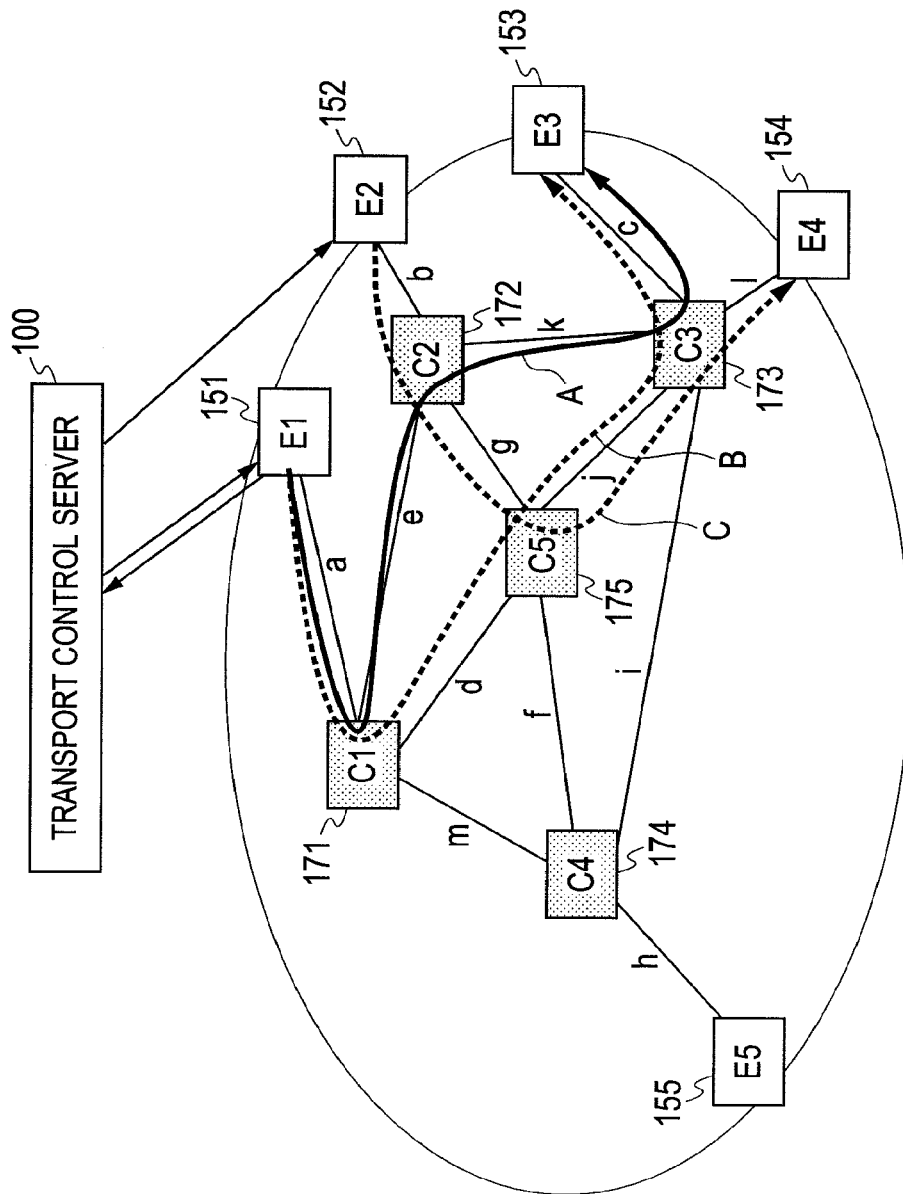


FIG. 5

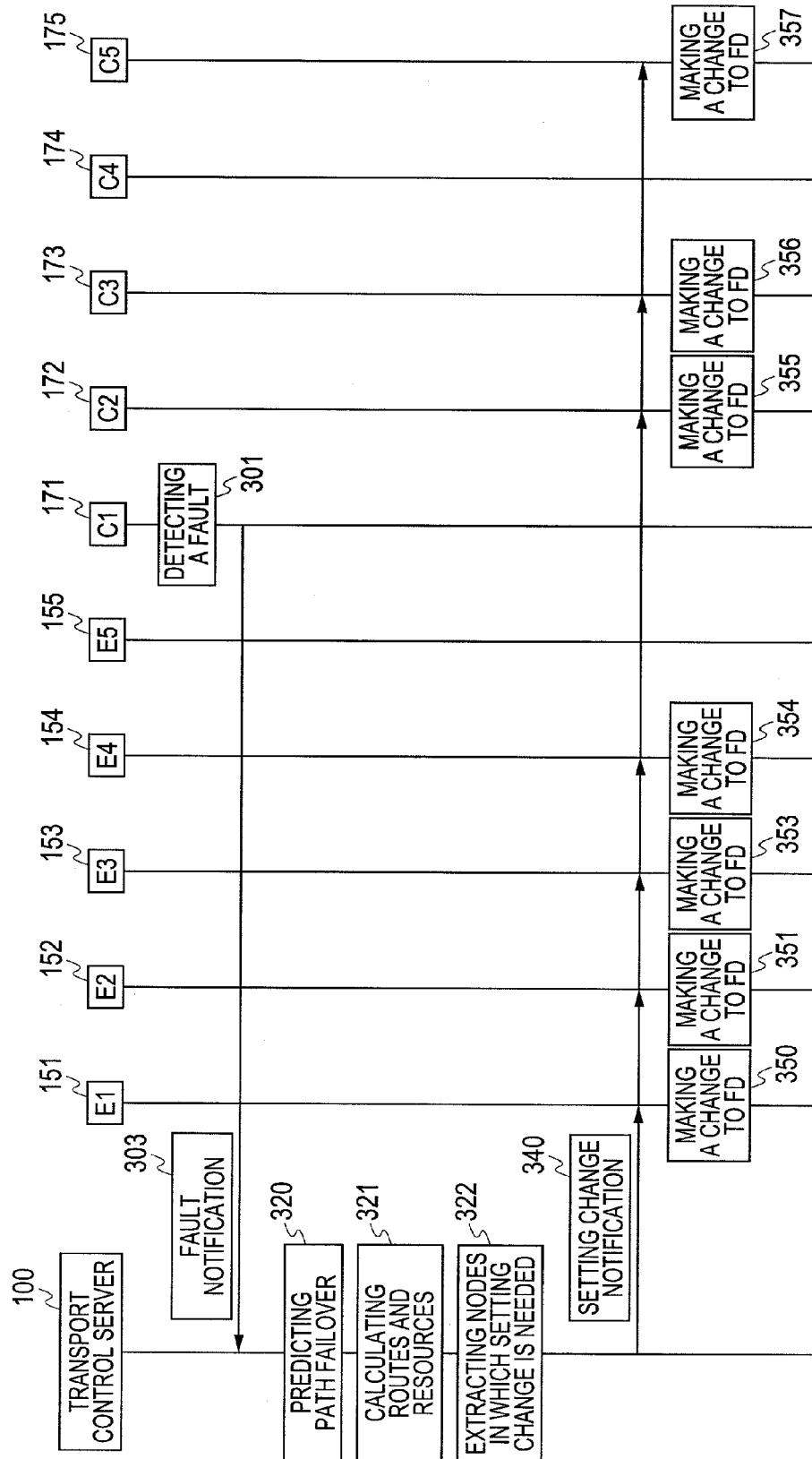


FIG. 6

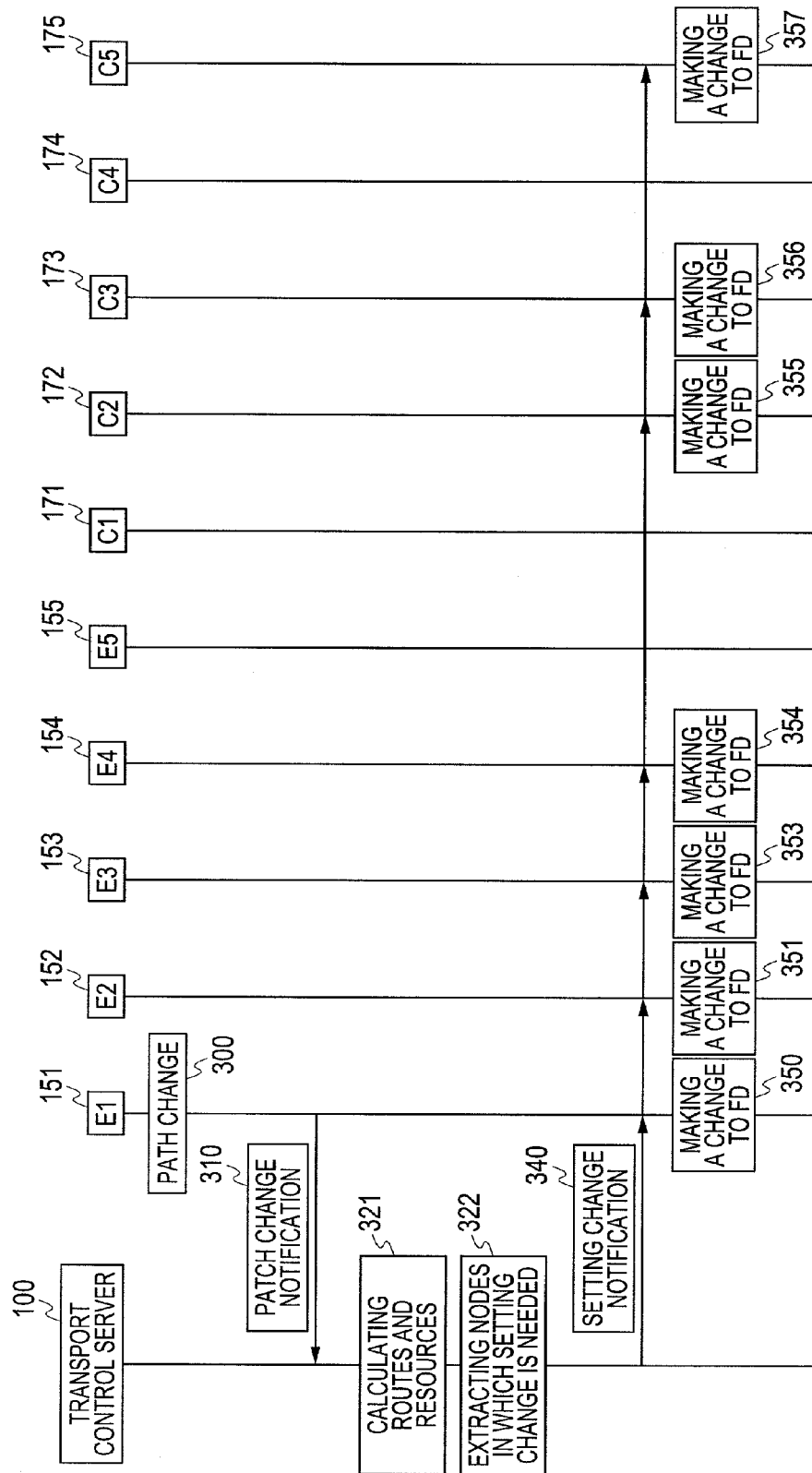


FIG. 7

STRUCTURAL DIAGRAM OF TRANSPORT CONTROL SERVER

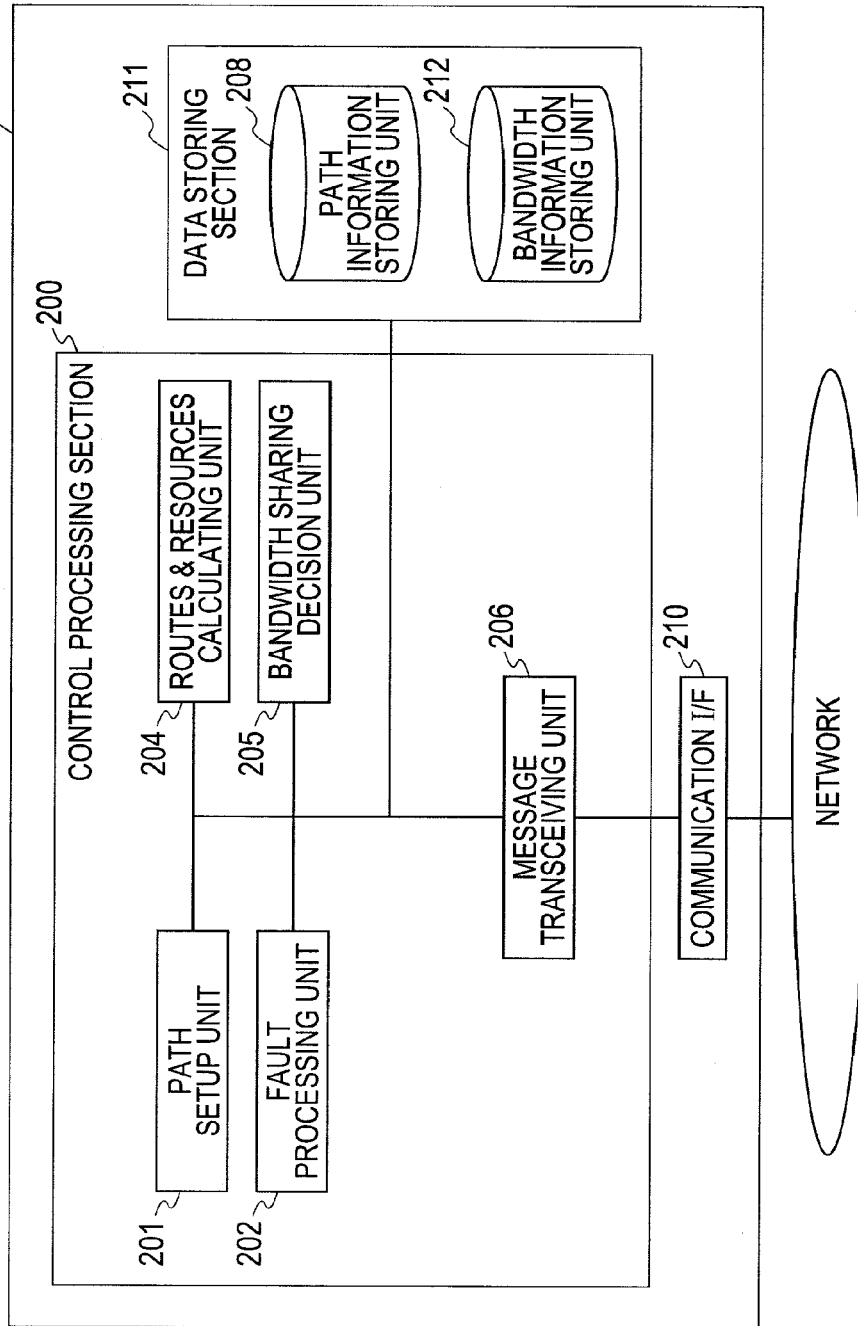


FIG. 8

700

401 ACTIVE PATH ID	402 ENDPOINT NODE	418 STANDBY PATH		403 CANDIDATE PATH ID	404 BANDWIDTH SHARING	419 BANDWIDTH OF PATH
A	E1 E2	B	O	E		20M
F	E2 E4	C	O	D G		10M

FIG. 9

705

405		406					407				
PATH ID		TRANSIT NODE					TRANSIT LINK				
A		E1	C1	C2	C3	E3		a	e	k	c
B		E1	C1	C5	C3	E3		a	d	j	l
C		E2	C2	C5	C3	E4		b	g	j	l
D		E2	C2	C5	C4	C3	E4	b	g	f	i

FIG. 10

715

405		406		435	440
PATH ID		TRANSIT NODE		INPUT LABEL & INTERFACE	OUTPUT LABEL & INTERFACE
A		E1		3, eth0	2, eth2
		C1		4, eth3	1, eth0
		C2		4, eth4	13, eth2
		C3		11, eth5	15, eth3
B					

FIG. 12

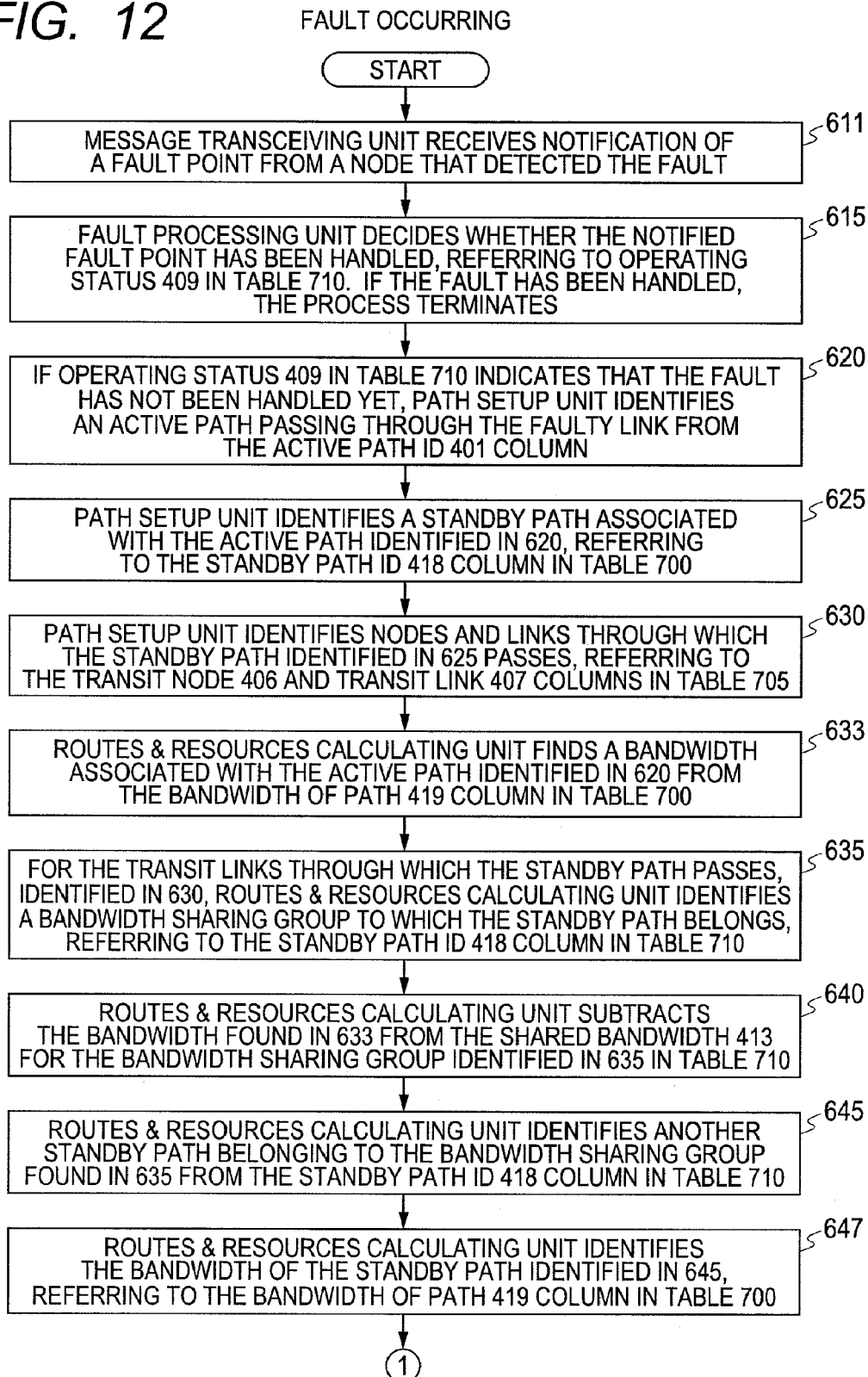


FIG. 13

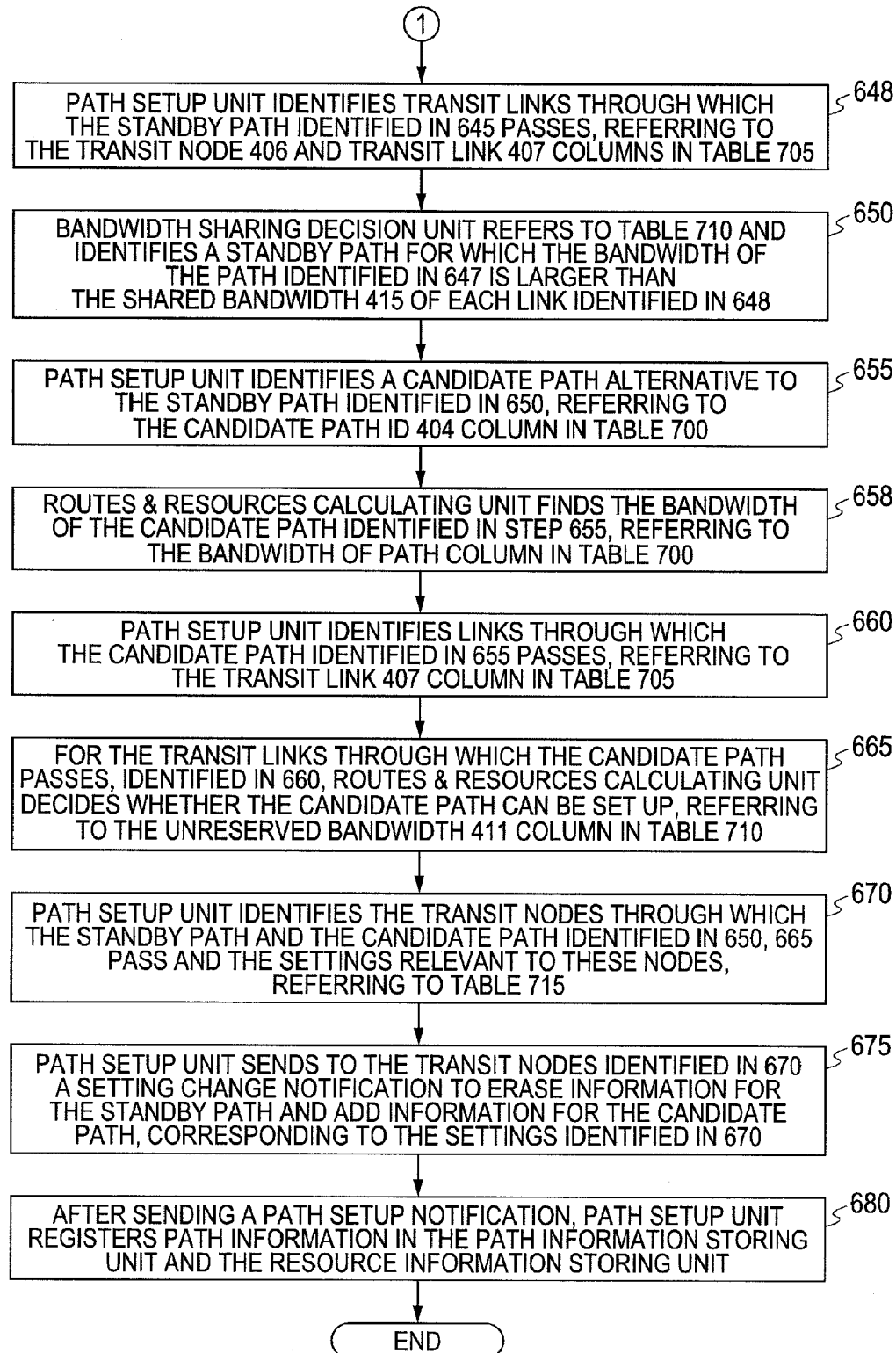
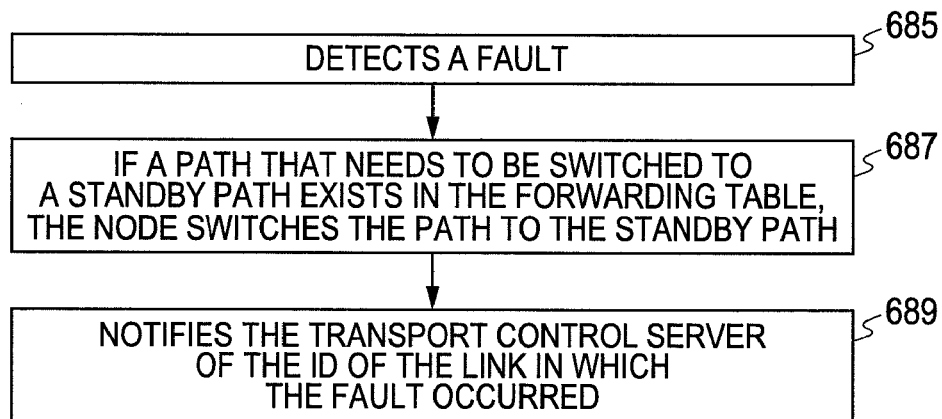


FIG. 14

OPERATION OF A CORE NODE HAVING DETECTED A FAULT

**FIG. 15**

OPERATION OF AN EDGE NODE UPON A FAULT OCCURRING

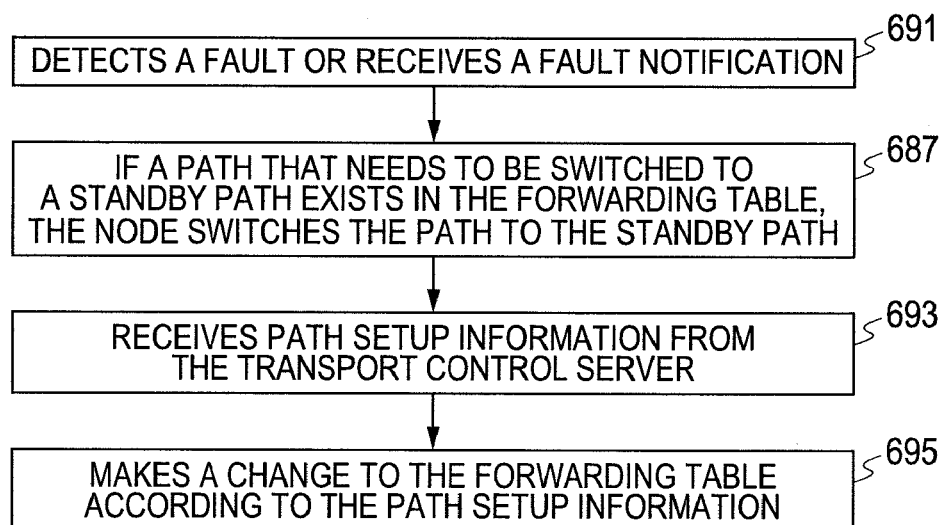


FIG. 16

OPERATION OF AN EDGE NODE WHEN THE EDGE NODE CHANGES PATH

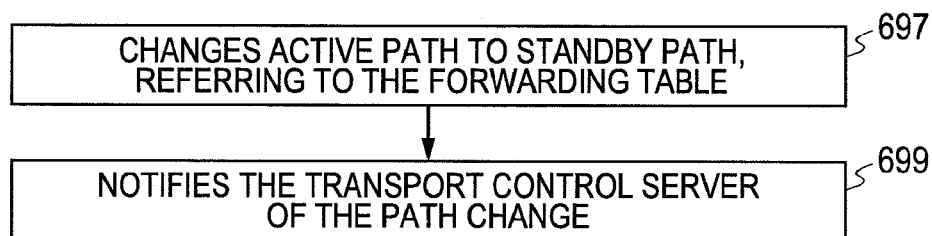


FIG. 17

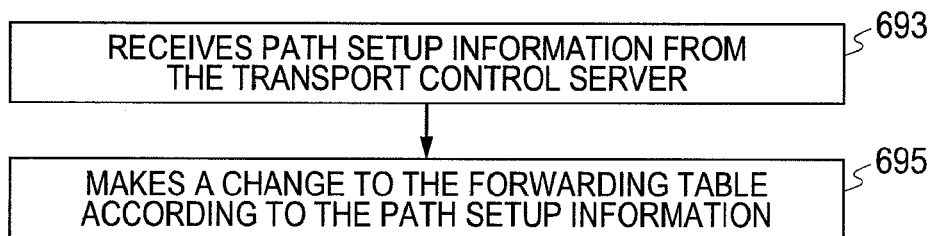


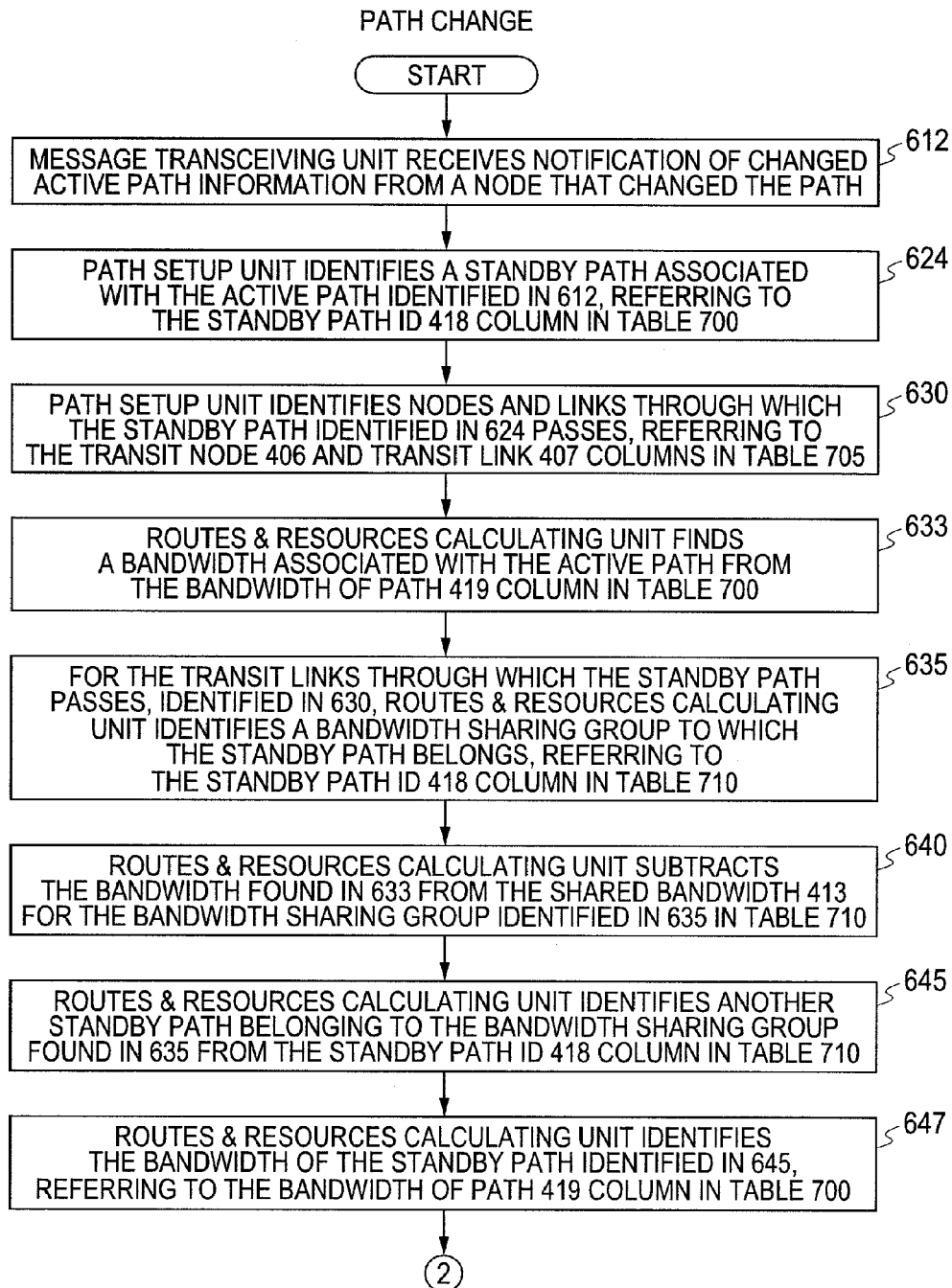
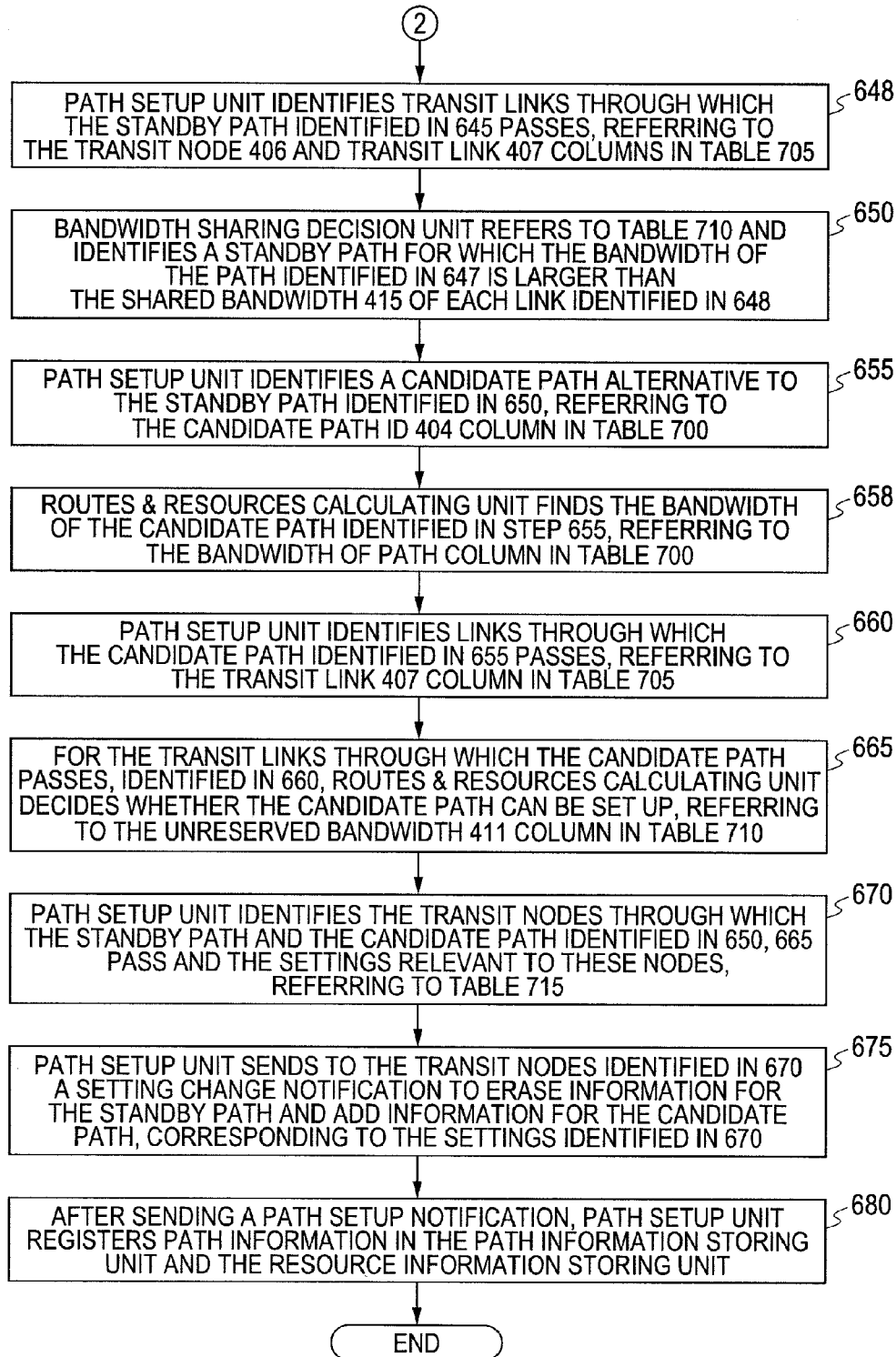
FIG. 18

FIG. 19



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TRANSPORT CONTROL SERVER, TRANSPORT CONTROL SYSTEM, AND BACKUP PATH SETTING METHOD

CROSS REFERENCE TO RELATED APPLICATION

This is a continuation of U.S. application Ser. No. 12/852,310, filed Aug. 6, 2010 (now U.S. Pat. No. 8,811,149), which application is related to U.S. application Ser. No. 12/637,929, filed Dec. 15, 2009 (now U.S. Pat. No. 8,547,850). This application relates to and claims priority from Japanese Patent Application No. 2009-188051, filed on Aug. 14, 2009. The entirety of the contents and subject matter of all of the above is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a transport control server (TCS), a transport control system, and a backup path setting method. In particular, the invention relates to a transport control server, a transport control system, and a backup path setting method, in a system where plural backup paths may share a link, for carrying out setting change in nodes along a path affected by a path switchover, when a path change is made by a node or when a node autonomously performs switching from an actually used path (active path) to an auxiliary path (backup path) due to a fault or congestion occurring.

BACKGROUND OF THE INVENTION

Path mechanisms such as MPLS (Multi-Protocol Label Switching), GMPLS (Generalized MPLS), MPLS-TP (MPLS Transfer Profile), and PBB-TE (Provider Backbone Bridge Traffic Engineering) have heretofore been proposed. In a network using such a path mechanism, link sharing in which plural backup paths may share the bandwidth of a link is proposed with the aim of efficient link bandwidth utilization (refer to IETF, "RSVP-TE Extensions For Shared-mesh Restoration in Transport Networks", Internet-Drafts December 2001). In the link sharing, all backup paths are set up so that their bandwidths are guaranteed in case of faults occurring, if not exceeding a predetermined number of faults. This approach allows plural backup paths having different endpoints, respectively, to share the bandwidth of a link and, therefore, provides more efficient bandwidth utilization than path sharing in which plural active paths may share a backup path (refer to IETF, "Framework for Multi-Protocol Label Switching (MPLS)-based Recovery", RFC 3469, February 2003).

Some techniques related to the link sharing have heretofore been disclosed, which are enumerated below: a method for advertising a shared bandwidth and a method for calculating a route (refer to JP-A No. 2003-273904); a method for setting up a high priority path preferentially in case of a fault occurring and a method for path setting by a centralized control server (refer to JP-A No. 2003-229889); and a path setting method taking wavelength into account (refer to JP-A No. 2005-210514).

SUMMARY OF THE INVENTION

JP-A No. 2003-273904 suggests a method in which each node maintains shared bandwidth information in a network and calculates an available backup path. In the network where plural backup paths may share the bandwidth of a link, con-

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sistent bandwidth information must be maintained on the nodes in the same network. If not so, multiple faults occurring may result in a possibility that a total of the bandwidths of plural backup paths exceeds the bandwidth for the backup paths allocated to a link. In this case, path switchover to a backup path through the link may cause congestion on that link. To avoid such condition, shared bandwidth information maintained by a node must be consistent with shared bandwidth information maintained by other nodes in the same network. Therefore, each time an edge node sets up or changes an outgoing path from it, the edge node needs to advertise shared bandwidth information to all other nodes and the nodes receiving this advertisement need to update the shared bandwidth information maintained therein. Consequently, the occurrence of a link fault or node fault causes a number of path changes and, therefore, a number of advertisements are transmitted mutually. Whenever receiving an advertisement, each node updates the shared bandwidth information. A problem is an increase in the processing loads of the nodes.

JP-A No. 2003-229889 suggests a method in which a transport control server manages the shared bandwidths of links, wherein, however, the labels of backup paths are not distributed. In order to make a faster recovery from a fault, the labels of paths need to be preconfigured in nodes so that a node can autonomously switch over to a backup path upon a fault occurring. However, in a case where these labels are preconfigured in the nodes, there is a possibility that plural backup paths have consumed the bandwidth for the backup paths allocated to a link, as discussed for JP-A No. 2003-273904. Therefore, when a node autonomously makes a path change, the transport control server must update the shared bandwidth information and notify nodes of a path that becomes unavailable. However, because a number of active paths are switched to backup paths upon a fault occurring, the transport control server must transmit a number of setting change notifications. A problem is an increase in the processing load of the transport control server.

As noted above, when an active path (first active path) is switched to a backup path (first backup path), a backup path (second backup path) for another active path (second active path) may become unavailable. For example, due to the use of the first backup path, it may become impossible to secure the bandwidth of the second backup path sharing a link with the first backup path. This notification is advertised to all nodes in the prior art techniques and, thus, entails a number of advertisements.

When a fault occurring causes switchover from active path to backup path, plural active paths passing through the fault point may be switched to backup paths, causing the changes to plural second backup paths. In that event, multiple advertisements of the changes to the second backup paths must be sent.

In view of the foregoing points, the present invention is intended to prevent a number of advertisements about shared bandwidths or a number of setting change notifications from being generated upon a fault occurring. The present invention is intended to identify nodes in which a backup path setting change is needed and transmit a backup path change notification to these nodes. The present invention is intended to transmit a notification of a backup path setting change on a per-fault basis. The present invention is intended to prevent repeated transmissions of a notification of a backup path setting change due to a fault.

The present invention relates to a network system wherein plural backup paths may share the bandwidth of a link, characterized in that a transport control server calculates a backup

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path that a node autonomously uses upon receiving a fault notification, erases the settings of a backup path predicted to become unavailable based on path information, topology information, and bandwidth information, selects a backup path alternative to the erased backup path from among candidate paths, and transmits a setting change notification to nodes in which the setting change is needed.

According to a first aspect of the present invention, a transport control server in a network system includes multiple nodes and the transport control server, in which a first backup path is predefined for a first active path between any pair of nodes and having a predetermined first bandwidth secured, a second backup path is predefined for a second active path between any pair of nodes and having a predetermined second bandwidth secured, the first backup path and the second backup path sharing at least one of links, and each node forwards data according to path setting information notified from the transport control server, and the transport control server includes:

- a storage section storing, for each path, the identifies of nodes through which the path passes, the first bandwidth of a first active path or first backup path, the second bandwidth of a second active path or second backup path, and auxiliary bandwidths per link allocated for backup paths; and

- a control processing section,
- in which the control processing section performs the following comprising:

- upon a switchover of a first active path to a first backup path, deciding whether the second bandwidth of a second backup path can be secured by the bandwidth of each of links through which the first backup path passes, referring to the storage section;

- if the second bandwidth cannot be secured, identifying nodes through which the second backup path passes, referring to the storage section; and

- transmitting a setting change notification to delete the second backup path to the identified nodes.

According to a second aspect of the present invention, a transport control system includes:

- multiple nodes; and

- a transport control server,

- in which a first backup path is predefined for a first active path between any pair of nodes and having a predetermined first bandwidth secured,

- a second backup path is predefined for a second active path between any pair of nodes and having a predetermined second bandwidth secured,

- the first backup path and the second backup path sharing at least one of links, and

- each node forwards data according to path setting information notified from the transport control server, and

- the transport control server includes:

- a storage section storing, for each path, the identifies of nodes through which the path passes, the first bandwidth of a first active path or first backup path, the second bandwidth of a second active path or second backup path, and auxiliary bandwidths per link allocated for backup paths; and

- a control processing section,

- in which the control processing section performs the following that includes:

- upon a switchover of a first active path to a first backup path, deciding whether the second bandwidth of a second backup path can be secured by the bandwidth of each of links through which the first backup path passes, referring to the storage section;

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- if the second bandwidth cannot be secured, identifying nodes through which the second backup path passes, referring to the storage section; and

- transmitting a setting change notification to delete the second backup path to the identified nodes.

According to a third aspect of the present invention, there is provided a backup path setting method for use in a network system including multiple nodes and a transport control server, in which a first backup path is predefined for a first active path between any pair of nodes and having a predetermined first bandwidth secured, a second backup path is predefined for a second active path between any pair of nodes and having a predetermined second bandwidth secured, the first backup path and the second backup path sharing at least one of links, and each node forwards data according to path setting information notified from the transport control server, and the backup path setting method includes:

- upon a switchover of a first active path to a first backup path, deciding whether the second bandwidth of a second backup path can be secured by the bandwidth of each of links through which the first backup path passes, referring to a storage section storing, for each path, the identifies of nodes through which the path passes, the first bandwidth of a first active path or first backup path, the second bandwidth of a second active path or second backup path, and auxiliary bandwidths per link allocated for backup paths;

- if the second bandwidth cannot be secured, identifying nodes through which the second backup path passes, referring to the storage section; and

- transmitting a setting change notification to delete the second backup path to the identified nodes.

According to an aspect of the present invention, it is possible to prevent a number of advertisements about shared bandwidths or a number of setting change notifications from being generated upon a fault occurring. According to another aspect of the present invention, it is possible to identify nodes in which a backup path setting change is needed and transmit a backup path change notification to these nodes. According to still another aspect of the present invention, it is possible to transmit a notification of a backup path setting change on a per-fault basis. According to yet another aspect of the present invention, it is also possible to prevent repeated transmissions of a notification of a backup path setting change due to a fault.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an architectural diagram of a transport control system;

FIG. 2 is an explanatory diagram of the transport control system, when setting up a path;

FIG. 3 is an explanatory diagram of the transport control system upon a fault occurring;

FIG. 4 is an explanatory diagram of the transport control system upon a path change;

FIG. 5 illustrates a signaling sequence in the transport control system upon a fault occurring;

FIG. 6 illustrates a signaling sequence in the transport control system upon a path change;

FIG. 7 is a structural diagram of a transport control server;

FIG. 8 illustrates a (first) path information table;

FIG. 9 illustrates a (second) path information table;

FIG. 10 illustrates a (third) path information table;

FIG. 11 illustrates a bandwidth information table;

FIG. 12 is a flowchart (1) of a process when the transport control server receives a fault notification;

FIG. 13 is a flowchart (2) of the process when the transport control server receives a fault notification;

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FIG. 14 is a flowchart of a process when a core node has detected a fault;

FIG. 15 is a flowchart of a process of an edge node upon a fault occurring;

FIG. 16 is a flowchart of a process when an edge node changes a path;

FIG. 17 is a flowchart of a process when an edge node receives a setting change notification;

FIG. 18 is a flowchart (1) of a process when the transport control server receives a path change notification;

FIG. 18 is a flowchart (1) of a process when the transport control server receives a path change notification; and

FIG. 19 is a flowchart (2) of the process when the transport control server receives a path change notification.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following, a network system pertaining to an embodiment of the invention will be described in detail with reference to the drawings. In the following, the same reference numerals denote the same items.

FIG. 1 is an architectural diagram of a network system of the present embodiment.

The network system comprises a transport control server 100 that acts as network control entity, edge nodes 151 to 155 that connect a core network managed by the transport control server 100 to another network or terminals, and core nodes 171 to 175 that make up the core network. Links a to h are shown as the links in the network.

The transport control server 100 connects to the edge nodes 151 to 155 and the core nodes 171 to 175 and, for example, sets up a path between edge nodes for connecting these edge nodes. Byway of example, path mechanisms such as MPLS, GMPLS, MPLS-TP, and PBB-TE can be used. In the network managed by the transport control server, endpoints of a path are considered as edge nodes.

FIG. 2 illustrates a relationship among the transport control server 100, edge nodes 151 to 155, and core nodes 171 to 175, when setting up a path.

The transport control server 100 manages topology information such as links and path information such as path routes, allocated bandwidths, shared bandwidths, labels, and tags for the edge nodes 151 to 155 and the core nodes 171 to 175.

When setting up a path whose endpoints are edge nodes 151 and 152 and passing through core nodes 171 and 172, the transport control server 100 calculates settings to be provided to the edge nodes 151, 152 and the core nodes 171, 172 and transmits a setting change notification. The edge nodes 151, 152 and the core nodes 171, 172 forward data according to the settings provided by the transport control server 100.

FIG. 3 illustrates a relationship among the transport control server 100, edge nodes 151 to 155, and core nodes 171 to 175, upon a fault occurring.

As an active path, an active path A is set up between endpoints of edge nodes 151, 153, passing through core nodes 171, 172, 173. As a backup path for the active path A, a backup path B is set up between the endpoints of edge nodes 151, 153, passing through core nodes 171, 175, 173. Further, as a backup path for an active path F (not shown) different from the active path A, a backup path C is set up between endpoints of edge nodes 152, 154, passing through core nodes 172, 175, 173. The backup path B and the backup path C share a bandwidth across a link j between the core nodes 175 and 173. The transport control server 100 manages the active path A, the backup paths B, C, and, moreover, a candidate path D which is used as an alternative to the backup path C. The

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candidate path D is routed between endpoints of edge nodes 152, 154, passing through core nodes 172, 175, 174, 173.

When a core node 171 detects a fault in a link e, it sends a fault notification to the transport control server 100 and the edge node 151, one endpoint of the active path A that passes through the core node 171 and the link e. Information in the fault notification includes a link ID, the identifier of the link in which the fault occurred. The edge node 151 autonomously switches the active path A passing through the fault point to the backup path B. Upon receiving the fault notification, the transport control server 100 predicts the active path A that is switched to the backup one due to the fault, identifies core nodes and links through which the active path A and the backup path B for the active path A pass, and calculates a change in the bandwidth across each of the links a, d, j, c thorough which the backup path B passes. With regard to the backup paths passing through the links d, j whose bandwidth changes, the transport control server 100 decides whether the backup path C that shares a link bandwidth has a sufficient bandwidth. If deciding that the bandwidth of the backup path C is insufficient, the transport control server 100 transmits a setting change notification to erase the backup path C with an insufficient bandwidth from the settings maintained on the edge nodes 152, 153 and the core nodes 172, 175, 173. If there is an available candidate path D instead of the backup path C, the transport control server 100 transmits a setting change notification to set up a new backup path D, when transmitting the setting change notification to erase the backup path C. In FIG. 3, the transport control server 100 manages the candidate path D alternative to the backup path C and, therefore, transmits the setting change notification to set up the backup path D to the edge nodes 152, 154 and the core nodes 172, 175, 174, 173. The edge nodes 152, 153, 154 and the core nodes 172, 175, 173, 174 make a change to the settings according to the notification from the transport control server 100.

FIG. 4 illustrates a relationship among the transport control server 100, edge nodes 151 to 155, and core nodes 171 to 175, when an edge node 151 autonomously changes an active path A to a backup path B.

While FIG. 3 illustrates a case where a fault has occurred in a link, the present embodiment can also be applied to a case where a path change occurs irrespective of whether or not a fault occurs. An active path A between the endpoints of edge nodes 151, 153 passes through core nodes 171, 172, 173. A backup path B for the active path A between the endpoints of edge nodes 151, 153 passes through core nodes 171, 175, 173. As a backup path for an active path F different from the active path A, a backup path C is set up between the endpoints of edge nodes 152, 154, passing through core nodes 172, 175, 173. The backup path B and the backup path C share a bandwidth across a link j between the core nodes 175 and 173.

Description is provided for the case where the edge node 151 has changed the active path A to the backup path B. When the edge node 151 autonomously switches the active path A to the backup path B, it transmits a path change notification to the path transport control server 100. Upon receiving the path change notification, the transport control server 100 identifies core nodes, edge nodes, and links through which the active path A and the backup path B pass and calculates a change in the bandwidth across each of the links a, d, j, c thorough which the backup path B passes. With regard to the backup paths passing through the links d, j whose bandwidth changes, the transport control server 100 decides whether the backup path C that shares a link bandwidth has a sufficient bandwidth. If deciding that the bandwidth of the backup path C is insufficient, the transport control server 100 transmits a

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setting change notification to erase the backup path C with an insufficient bandwidth from the settings maintained on the edge nodes **152, 154** and the core nodes **172, 175, 173**. If there is an available candidate path instead of the backup path C, the transport control server **100** also transmits a setting change notification to set up a new backup path, when transmitting the setting change notification to erase the backup path C. The edge nodes **152, 153, 154** and the core nodes **172, 175, 173** make a change to the settings according to the notification from the transport control server **100**.

FIG. 5 illustrates an example of signaling sequence between the transport control server **100** and the edge nodes **151** to **155** as well as the core nodes **171** to **175** upon a fault occurring.

At step **301**, a core node **151** detects a fault. This fault detection detects a link fault or a node fault such as, e.g., Sonet Alarm, but not detecting a fault on a per-path basis. At step **303** a fault notification is transmitted from the core node **151** to the transport control server **100**. The fault notification includes, inter alia, information indicating a fault point (e.g., the ID of a faulty link). At step **320**, the transport control server **100** identifies the active path passing through the fault point and finds a backup path to be used and links through which the backup path passes. At step **321**, the transport control server **100** recalculates the bandwidths of the links through which the backup path passes. At step **322**, the transport control server **100** finds a backup path with an insufficient bandwidth out of backup paths passing through links whose bandwidth was altered and extracts edge nodes and core nodes through which the backup path passes. If the transport control server **100** manages a candidate path alternative to the backup path with an insufficient bandwidth, it extracts edge nodes and core nodes in which setting is needed to use the candidate path as a backup path. At step **340**, the transport control server **100** transmits a setting change notification to the core nodes **151** to **154** and edge nodes **172, 173, 175** in which setting change is needed. At steps **350** to **357**, the core nodes **151** to **154** and edge nodes **172, 173, 175** make a change to a forwarding database maintained therein according to the setting change notification in step **340**.

FIG. 6 illustrates an example of signaling sequence between the transport control server **100** and the edge nodes **151** to **155** as well as the core nodes **171** to **175** upon a path change occurring.

At step **300**, an edge node **151** changes the active path to the backup path. Such path change is triggered by fault detection on a per-path basis, such as, e.g., CV (Connection Verification) and FFD (Fast Fault Detection). At step **310**, a path change notification is transmitted from the edge node **151** to the transport control server **100**. The path change notification may include anyone or more of the following items of information: the labels or tags of the active path failed and the backup path switched over to, the ID of the node that switched the active path to the backup path, and information about the fault detection that triggered the switching. At step **321**, the transport control server recalculates the bandwidths of links through which the backup path passes. At step **322**, it finds a backup path with an insufficient bandwidth out of backup paths passing through links whose bandwidth was altered and extracts edge nodes and core nodes through which the backup path passes. If the transport control server **100** manages a candidate path alternative to the backup path with an insufficient bandwidth, it extracts edge nodes and core nodes in which setting is needed to use the candidate path as a backup path. At step **340**, the transport control server **100** transmits a setting change notification to the edge nodes **151** to **154** and core nodes **172, 173, 175** in which setting change is needed.

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At steps **350** to **357**, the edge nodes **151** to **154** and core nodes **172, 173, 175** make a change to the forwarding database maintained therein according to the setting change notification in step **340**.

FIG. 7 shows a structural diagram of the transport control server **100**.

The transport control server **100** comprises a control processing section **200**, a data storing section **211**, and a communication IF **210**. The control processing section **200** comprises a path setup unit **201**, a fault processing unit **202**, a routes and resources calculating unit **204**, a bandwidth sharing decision unit **205**, and a message transceiving unit **206**. The data storing section **211** comprises a path information storing unit **208** and a bandwidth information storing unit **212**. The path information storing unit **208** includes first, second, and third tables which will be described later. Topology information may further be stored in the data storing section **211**. The transport control server **100** may further comprise an input section.

The path setup unit **201** sets a path connecting edge nodes **151** to **154** and core nodes **171** to **175**. The fault processing unit **202**, when receiving a network fault notification, decides whether the fault notification has already been handled or it is about a new fault and identifies an active path failed and a backup path switched over to. The routes and resources calculating unit **204** finds the routes of active paths and backup paths and calculates bandwidths that are secured for each of the active paths and backup paths. The bandwidth sharing decision unit **205** finds a backup path that becomes unavailable, based on the results of the calculation of the routes and resources calculating unit **204**.

FIG. 8 illustrates a part (first table) of the path information storing unit **208**.

The first table **700** contains information in the following columns: active ID **401**, endpoint node **402**, backup path **403**, candidate path ID **401**, and bandwidth of path **419**. For active path IDs **401**, appropriate identification information such as, e.g., sequential numbers, alphabetic letters, etc. to identify active paths may be used. Endpoint nodes **402** in a pair indicate the endpoints of a path, the source and destination of communication via the path, and the IDs of these nodes are stored. The backup path **403** column comprises a backup path ID **418** column for backup path identifiers and a bandwidth sharing **420** column to indicate whether or not bandwidth sharing is applied. Candidate path IDs **404** are the identifiers of third optional paths managed by the transport control server **100**, aside from active paths and backup paths which are set on the nodes. For candidate path IDs, identification information, for example, like active path IDs **401** may be used. The bandwidth of path **419** column contains information for a bandwidth secured for the active path designated in the active path ID **401** column.

FIG. 9 illustrates a part (second table) of the path information storing unit **208**.

The second table **705** contains information in the following columns: path ID **405**, transit node **406**, and transit link **407**. The path ID **405** column contains the identifiers of paths such as active path IDs **401**, backup path IDs **418**, and candidate path IDs designated in the first table **700**. In the transit node **406** column, the identifiers of nodes through which the path passes may be specified. In the transit link **407** column, the identifiers of links through which the path passes may be specified.

FIG. 10 illustrates a part (third table) of the path information storing unit **208**.

The third table **715** contains information in the following columns: path ID **405**, transit node **406**, input label and inter-

face **435**, and output label and interface **440**. The path ID **405** column contains the identifiers of active paths, backup paths, and candidate paths. The transit node **406** column contains the identifiers of nodes through which the path passes. The input label and interface **435** information comprises a path input interface and its label of each transit node along the path identified by the path ID **405**, wherein this label has to be included in the header of a packet. The output label and interface **440** information comprises a path output interface and its label of each transit node along the path identified by the path ID **405**, wherein this label has to be specified in the header of a packet.

FIG. 11 illustrates a part (fourth table) of the bandwidth information storing unit **212**.

The bandwidth information storing unit **212** stores information, e.g., in the following columns: link ID **408**, operating status **409**, link bandwidth **410**, unreserved bandwidth **411**, actually used bandwidth **412**, auxiliary bandwidth **413**, and path ID of path passing through link **417**. In link ID **408** column, the identifiers of links may be specified. The operating status **409** column can indicate whether the link is in normal operation or abnormal condition. A flag value in the operating status **409** column is turned to an abnormal indication when the transport control server **100** receives a fault notification and turned to a normal indication when this flag is reset by the user. The link bandwidth **410** column indicates a maximum link bandwidth at which data is transported across the link. The unreserved bandwidth **411** column can indicate a bandwidth not secured for an active path and a backup path. The actually used bandwidth **412** column can indicate a total of the bandwidths of all active paths passing through the link. The actually used bandwidth **412** column comprises an occupied bandwidth **414** column and a shared bandwidth **414** column. The occupied bandwidth **414** column can indicate a total of the bandwidth of backup paths that do not share a bandwidth with any other backup path. The shared bandwidth **414** column can indicate a total of the bandwidths of backup paths in each of several groups SRG1, SRG2, SRG3, etc. in areas where faults are liable to occur simultaneously. The path ID of path passing through link **417** column comprises an active path ID column **401**, a backup path ID **418** column, and a candidate path ID **417** column for active, backup, and candidate paths passing through the link. In the backup path ID **418** column, backup path IDs sorted by occupied bandwidth and SRG as in the auxiliary bandwidth column can be stored.

FIG. 12 and FIG. 13 illustrate a flowchart of a process when the transport control server **100** receives a fault notification.

At step **611**, the message transceiving unit **206** receives fault notification information from a node that detected a fault. The fault notification information includes the ID of a link in which a fault occurred. At step **615**, the fault processing unit **202** refers to the operating status **409** associated with the link ID **408** included in the fault notification information in the fourth table **710**. The operating status may have two flag values corresponding to normal and abnormal indications. If the operating status **409** is an abnormal indication, the fault processing unit **202** decides that the fault has already been handed and terminates the process. If the operating status **409** is a normal indication ("O" as in FIG. 11), the fault processing unit **202** turns the value of the operating status **409** associated with the link ID **408** included in the fault notification information to an abnormal indication and the process goes to step **620**. The values corresponding to the normal and abnormal indications can be predetermined.

At step **620**, the path setup unit **201** identifies an active path passing through the link, referring to the fourth table **710** and the active path ID **401** column in the row (entry) of the link ID

408 matching the link ID included in the fault notification information. If multiple active paths pass through the link, the following steps **625** to **670** are repeated times as many as the number of the active paths. If the corresponding cell of active path ID **410** is empty, the process terminates.

At step **625**, the path setup unit **201** identifies a backup path, referring to the first table **700** and the backup path ID **418** column in the row of the active path ID **401** matching the ID of the active path identified in step **620**. The thus identified backup path is the path switched from the active path autonomously by one of the nodes **151** to **155** upon the occurrence of the notified fault and traffic now flows on this path. If the corresponding cell of backup path ID **418** is empty, the process terminates. At step **630**, the path setup unit **201** identifies nodes and links through which the backup path passes, referring to the second table **705** and the transit node **406** and transit link **407** columns in the row of the path ID **405** matching the ID of the backup path identified in step **625**. If the backup path passes through multiple links, the following steps **635** to **670** are repeated times as many as the number of the links.

At step **633**, the routes and resources calculating unit **204** finds a bandwidth of the active path identified in step **620**, referring to the first table **700** and the bandwidth of path **419** column in the row of the active path ID **401** matching the ID of the active path identified in step **620**. Upon switching from the active path to the backup path, the same bandwidth as the active path is secured for the backup path. In the first table **700**, hence, the bandwidth of the backup path is regarded as equivalent to the bandwidth of the active path.

At step **635**, the routes and resources calculating unit **204** identifies a bandwidth sharing group including the ID of the backup path identified in step **625**, referring to the fourth table **710** and the backup path ID **418** column in the row of the link ID **408** matching the ID of a transit link through which the backup path passes identified in step **630**. At step **640**, the routes and resources calculating unit **204** subtracts the bandwidth of the path found in step **633** from the shared bandwidth **415** in the column of the bandwidth sharing group identified in step **635** in the row of the link ID **408** matching the ID of a link identified in step **630** in the fourth table **710**. The bandwidth in the column is updated to the result of the subtraction. The thus updated bandwidth will be referred to as a regulated shared bandwidth hereinafter.

At step **645**, the routes and resources calculating unit identifies a backup path ID different than the backup path ID identified in step **625**, which belongs to the same bandwidth sharing group as identified in step **635** in the backup path ID **418** column, in the row of the link ID **408** matching the ID of a transit link through which the backup path (first backup path) passes identified in step **630** in the fourth table **710**. The backup path identified in this step will be referred to as an associated backup path (second backup path) hereinafter. If there are multiple associated backup paths, steps **647** to **670** are repeated times as many as the number of the associated backup paths. If there is no associated backup path, the process goes to step **672**.

At step **647**, the routes and resources calculating unit **204** finds a bandwidth (second bandwidth) necessary for the associated backup path, referring to the first table **700** and the bandwidth of path **419** column in the row of the backup path ID **418** matching the ID of the associated backup path identified in step **645**.

Proceeding to FIG. 13, at step **648**, the path setup unit **201** identifies nodes and links through which the associated backup path passes, referring to the second table **705** and the transit node **406** and transit link **407** columns in the row of the

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path ID **405** matching the ID of the associated backup path identified in step **645**. If the backup path passes through multiple links, step **650** is repeated times as many as the number of the links.

At step **650**, the bandwidth sharing decision unit **205** locates in the fourth table **710** the row of the link ID **408** matching the ID of a transit link identified in step **648** and identifies a backup path for which the bandwidth of the path found in step **647** is larger than the bandwidth (the regulated shared bandwidth updated in step **640**) of the bandwidth sharing group identified in step **635**. The backup path identified in this step will be referred to as an affected backup path hereinafter. If multiple affected backup paths are identified in this step, steps **655** to **670** are repeated times as many as the number of the affected backup paths.

At step **655**, the path setup unit **201** identifies a new candidate path alternative to the affected backup path, referring to the first table **700** and the candidate path ID **404** column in the row of the backup path ID **418** matching the ID of the affected backup path identified in step **650**. At step **658**, the routes and resources calculating unit **204** finds a bandwidth necessary for setting up the candidate path, referring to the first table **700** and the bandwidth of path **419** column in the row of the candidate path ID **404** matching the ID of the candidate path identified in step **655**. At step **660**, the path setup unit **201** identifies links through which the candidate path passes, referring to the second table **705** and the transit link **407** column in the row of the path ID **405** matching the ID of the candidate path identified in step **655**. At step **665**, for each of the links identified in step **660**, the routes and resources calculating unit **204** decides whether the bandwidth found in step **658** is smaller than the unreserved bandwidth **411** in the row of the link ID **408** matching the ID of a transit link identified in step **660**. If the bandwidth found in step **658** is smaller than the unreserved bandwidth with regard to all transit links, the routes and resources calculating unit **204** decides to set up the candidate path identified in step **655** as a new backup path alternative to the affected backup path identified in step **655**. If there is no candidate path satisfying the condition, it is decided that a new backup path does not exist. The new backup path identified in this step will be referred to as a new backup path hereinafter.

At step **670**, the path setup unit **201** identifies nodes required to delete the affected backup path and set up the new backup path and settings relevant to the nodes, referring to the third table **715** and the transit nodes associated with the path ID **405** matching the ID of the affected backup path identified in step **650** and the path ID **405** matching the ID of the new backup path decided in step **665** and the values of input label and interface **435** and output label and interface **440** in the rows of the transit nodes. If a new backup path does not exist, as decided in step **665**, the above step only applies to the affected backup path. The values as the label of the affected backup path are to be erased from the forwarding table in the transit nodes associated with the path. The values as the input label and interface and the output label and interface of the new backup path are to be added to the table in the transit nodes associated with the path.

At step **675**, the message transceiving unit **206** sends to the transit nodes associated with the affected backup path, identified in step **670**, a setting change notification to delete the values of the input label and interface and the output label and interface of the affected backup path. It also sends to the transit nodes associated with the new backup path, identified in step **670**, a setting change notification to add the values of the input label and interface and the output label and interface

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of the new backup path. If a new backup path does not exist, as decided in step **665**, the above step only applies to the affected backup path.

At step **680**, the path setup unit **201** deletes the ID of the affected backup path identified in step **650** from the backup path ID **418** column of the first table **700**. If a new backup path exists, as decided in step **665**, it also deletes the ID of the new backup path from the candidate path ID **404** column of the first table **700** in the row in which the affected backup path ID was deleted, adds the new backup path ID to the backup path ID **418** column in the same row, and changes the bandwidth sharing **420** column in the same row to a value indicating the state of the path that does not share a bandwidth. Further, the path setup unit **201** accesses the entries in the link ID **408** column of the fourth table **710**, matching the transit links identified in step **660**, and subtracts the bandwidth of path found in step **658** from the unreserved bandwidth **411** in the corresponding rows. The foregoing steps may be executed by appropriate blocks in the control processing section **200**.

FIG. **18** and FIG. **19** illustrate a flowchart of a process when the transport control server **100** receives a path change notification.

At step **612**, the message transceiving unit **206** receives a path change notification from a node that changed a path. The path change notification information includes the ID of an active path that the node changed. At step **624**, the path setup unit **201** identifies a backup path, referring to the first table **700** and the backup path ID **418** column in the row of the active path ID **401** matching the ID of the active path identified in step **612**. If the corresponding cell of backup path ID **418** is empty, the process terminates. The path change notification may include the ID of a backup patch switched over to from the active path. In this case, both active path and backup path can be identified from the information included in the path change notification.

Step **630** and subsequent steps are the same as those of the foregoing process upon a fault occurring illustrated in FIG. **12** and FIG. **13**.

FIG. **14** illustrates a flowchart of a process when a core node has detected a fault. By way of example, a case is described where a core node **171** detects a fault in a link **e**. The same applies to other cases when any other core node detects a fault in a link.

At step **685**, the core node **171** detects a fault in the link **e** connected to the core node. At step **687**, the core node **171** refers to the forwarding table maintained therein and decides whether there is a path that forwards traffic onto the faulty link detected and a backup path alternative to the path was set up. If there is such an active path for which a backup path was set up, the node switches the output interface and label from the output interface and output label of the active path to the output interface and output label of the backup path and forwards traffic. At step **689**, the core node **171** sends a fault notification to the transport control server **100** and the edge nodes **151** to **155**. Information in the fault notification includes the ID of the link in which the fault occurred.

FIG. **15** illustrates a flowchart of a process of an edge node upon a fault occurring. By way of example, the process of an edge node **151** is described. The same applies to other edge nodes.

At step **691**, the edge node **151** detects that a fault has occurred in a link **e** through which an outgoing path from the node passes or receives a fault notification from the core node **171** that detected the fault. At step **687**, the edge node **151** refers to the forwarding table managed therein and decides whether there is an active path that passes through the faulty link detected and a backup path alternative to the active path

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was set up. If there is such an active path for which a backup path was set up, the node switches the output interface and label from the output interface and output label of the active path to the output interface and output label of the backup path and forwards traffic.

At step 693, the edge node 151 receives a setting change notification from the transport control server 100. The setting change notification includes the values of the input label and interface and the output label and interface of the affected backup path and the values of the input label and interface and the output label and interface of the new backup path. At step 695, the edge node 151 makes a change to the forwarding database according to the setting change notification received in step 693.

FIG. 16 illustrates a flowchart of a process when an edge node 151 has changed a path.

At step 697, for example, upon a fault occurring on an active path, the edge node 151 autonomously changes the active path to a backup path, according to the forwarding table managed therein. In particular, the node switches the output interface and label from the output interface and output label of the active path to the output interface and output label of the backup path and forwards traffic. At step 699, the edge node 151 notifies transport control server 100 of the path change. This notification includes the ID of the path changed to the backup path.

FIG. 17 illustrates a flowchart of a process when an edge node 151 receives a setting change notification.

At step 693, the edge node 151 receives a setting change notification from the transport control server 100. The setting change notification includes the values of the input label and interface and the output label and interface of the affected backup path, which are to be deleted, and the values of the input label and interface and the output label and interface of the new backup path, which are to be added. At step 695, the edge node 151 makes a change to the forwarding database according to the setting change notification received in step 693.

[A Configuration Example of the Transport Control Server]

A transport control server of the present embodiment, for example, in a network system including multiple nodes and the transport control server, in which a node forwards data according to path setting information notified from the transport control server, the transport control server includes:

- a path setup unit for managing and setting active paths which are normally used, backup paths which are used in case of a fault, and candidate paths which are used when active and backup paths have become unavailable;

- a routes and resources calculating unit path for calculating path routes and bandwidths that should be secured;

- a bandwidth sharing decision unit for managing bandwidth sharing by plural backup paths;

- a fault processing unit for performing fault processing, when receiving a fault notification in the network;

- a message transceiving unit for transmitting and receiving a message to/from each of the nodes,

- a path information storing unit for storing information for paths;

- a topology information storing unit for storing topology information; and

- a bandwidth information storing unit for storing bandwidth information for links.

The transport control server calculates a backup path switched over to from an active path due to a path change or a fault, based on information in a path change notification or a fault notification, identifies a backup path affected by the switchover from the active path to the backup path, identifies

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nodes in which a setting change is needed, and transmits a setting change notification to the nodes.

In the above transport control server, for example, when calculating a backup path switched over to from an active path due to a fault in the network system, the fault processing unit calculates an active path passing through the fault point and a backup path to which the active path is switched, referring to topology information and path information in combination.

In the above transport control server, for example, when identifying a backup path affected by the switchover from the active path to the backup path in the network system, the bandwidth sharing decision unit calculates links through which the active path passing through the fault point passes and links through which the backup path to which the active path is switched passes by referring to topology information and path information in combination and finds an affected backup path by referring to other backup paths passing through the links.

The above transport control server, for example, when identifying nodes in which a setting change is needed in the network system, calculates an affected backup path that becomes unavailable, finds nodes through which the unavailable backup path passes, thereby finding the nodes in which a setting change is needed.

In the above transport control server, for example, once having identified the backup path affected by the switchover from the active path to the backup path in the network system, the path setup unit finds an available backup path from candidate paths as an alternative to the unavailable backup path by referring to topology information and path information in combination without performing path finding.

In the above transport control server, for example, when calculating a backup path switched over to from an active path due to a fault in the network system, the fault processing unit decides whether calculating an active path and a backup path according to a fault notification received is already done, referring to topology information. This avoids recalculating an active path and a backup path according to fault notifications about the same fault from a plurality of nodes.

In the above transport control server, for example, when identifying a backup path affected by the switchover from the active path to the backup path due to a path change in the network system, the fault processing unit calculates links through which the active path and the backup path to which the active path is switched pass by referring to topology information and path information in combination and finds a backup path that becomes unavailable by referring to other backup paths passing through the links.

The present invention can be applied to, for example, a network system where plural backup paths may share the bandwidth of a link.

What is claimed is:

1. A path control server for controlling a plurality of nodes in communication with the path control server, the path control server comprising one or more processors programmed with logic configured to:

- receive a notification from a first node of the plurality of nodes,

- determine from the notification whether any of the plurality of nodes in a third path are affected by the notification resulting in a path switch from a first path to a second path,

- identify one or more of the plurality of nodes in the third path to be notified of a setting change to delete the third path resulting from the path switch, the third path being different from the first and second paths and sharing at least one link with the second path, and

notify the one or more of the plurality of nodes on the third path to perform the setting change to delete the third path.

2. The path control server of claim 1, wherein the one or more nodes on the third path is joined to the at least one link shared with the second path, and wherein the third path and the second path share a bandwidth on the at least one link. 5

3. The path control server of claim 1, wherein the path control server receives the notification from any of the plurality of nodes. 10

4. The path control server of claim 1, wherein the notification comprises a notification of an occurrence of a failure in the first path.

5. The path control server of claim 4, wherein the failure comprises a link failure or a node failure in the first path. 15

6. The path control server of claim 1, wherein the first path is an active path, the second path is an alternative path for the active path, and the third path is another alternative path for another active path.

7. The path control server of claim 1, further configured to determine whether the third path has a sufficient bandwidth. 20

8. The path control server of claim 1, further configured to identify the first path and the second path based on the notification.

9. The path control server of claim 1, wherein the notification comprises at least one of a label of an active path, a label of an alternative path, tag information of the active path, tag information of the alternative path, and an identifier of a node that switched the active path to the alternative path. 25

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